The Claims

What is claimed is:

1. A planar motor comprising:

a coil array having a plurality of coils, each coil fixed in position with respect to the other coils;

a magnet array having a plurality of magnets, each magnet fixed in position with respect to the other magnets, the magnet array being movable above the coil array in at least two degrees of translational freedom and at least one degree of rotational freedom; and

a model-based predictive torque controller comprising a nonlinear current switching model, the torque controller configured to provide current to energize each coil in response to the position of each magnet with respect to a coil;

wherein the torque controller provides currents to the coil array to at least substantially reduce force ripple during movement of the magnet array.

2. The planar motor of claim 1, wherein the torque controller simultaneously stabilizes translational and rotational movement.

3. The planar motor of claim 1, wherein the torque controller compensates for torque produced by translation.

4. The planar motor of claim 1, wherein the coil array is square.

5. The planar motor of claim 4, wherein the coil array comprises at least 25 coils.

6. A method for controlling a planar motor for movement in three degrees of freedom, the method comprising:

positioning a movable magnet array over a fixed coil array, said coil array having coils generally disposed in a plane defining first and second directions that are substantially orthogonal to one another, and said magnet array having magnets with magnetic fields;

applying currents to said coils following a nonlinear current switching model to control movement of said magnet array and substantially reduce force ripple during said movement.

7. The method of claim 6, further comprising:

determining a first translational force for said magnet array in said first direction and a second translational force for said magnet array in said second direction.

8. The method of claim 6, further comprising:

determining a torque for said magnet array in a third direction perpendicular to said first and second directions.

9. A planar motor comprising:

magnet array means;

coil array means; and

control means providing electric current to said coil array means for controlled movement of said magnet array means in three degrees of freedom including non-linear current switching means for at least substantially reducing force ripple during movement of said magnet array.

10. A stage system comprising a planar motor, said planar motor comprising:

a coil array having a plurality of coils, each coil fixed in position with respect to the other coils;

a magnet array having a plurality of magnets, each magnet fixed in position with respect to the other magnets, the magnet array being movable above the coil array in at least two degrees of translational freedom and at least one degree of rotational freedom; and

a model-based predictive torque controller comprising a nonlinear current switching model, the torque controller configured to provide current to energize each coil in response to the position of each magnet with respect to a coil;

wherein the torque controller provides currents to the coil array to at least substantially reduce force ripple during movement of the magnet array.

11. An exposure apparatus comprising an illumination system that supplies radiant energy and a stage system comprising a planar motor, the planar motor comprising:

a coil array having a plurality of coils, each coil fixed in position with respect to the other coils;

a magnet array having a plurality of magnets, each magnet fixed in position with respect to the other magnets, the magnet array being movable above the coil array in at least two degrees of translational freedom and at least one degree of rotational freedom; and

a model-based predictive torque controller comprising a nonlinear current switching model, the torque controller configured to provide current to energize each coil in response to the position of each magnet with respect to a coil;

wherein the torque controller provides currents to the coil array to at least substantially reduce force ripple during movement of the magnet array, and wherein the stage system carries at least one object disposed on a path of the radiant energy.

12. A device manufactured with the exposure apparatus of claim 11.

13. A wafer comprising an image, wherein said image is formed with an exposure apparatus comprising an illumination system that supplies radiant energy and a stage system comprising a planar motor, the planar motor comprising:

a coil array having a plurality of coils, each coil fixed in position with respect to the other coils;

a magnet array having a plurality of magnets, each magnet fixed in position with respect to the other magnets, the magnet array being movable above the coil array in at least two degrees of translational freedom and at least one degree of rotational freedom; and

a model-based predictive torque controller comprising a nonlinear current switching model, the torque controller configured to provide current to energize each coil in response to the position of each magnet with respect to a coil;

wherein the torque controller provides currents to the coil array to at least substantially reduce force ripple during movement of the magnet array, and wherein the stage system carries at least one object disposed on a path of the radiant energy.